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1. Field of the Invention

The present invention relates to a method and apparatus for avoiding starvation in a computer network.

2. Description of the Related Art

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According to the present invention, there is also provided an apparatus for implementing each of the above methods. According to the present invention, there is also provided a recording medium readable by the apparatus and storing thereon a program for implementing each of the above methods.

Further features and advantages of the present invention will be apparent from the following description with reference to the accompanying drawings, in which:

Figure 2 is a diagram showing one example of the hardware configuration of a target node carrying out the present invention;

Figures 4A and 4B are a flowchart illustrating the

sequence of processing performed at the target node when a request is received;

Figure 5 is a flowchart illustrating the sequence of processing performed at the initiator node when a reply packet is received;

Figure 6 is a diagram showing various states of the target nodes and actions and state transitions occurring at the target nodes;

Figure 7 is a sequence chart showing one typical operational example, and

Figure 8 is a sequence chart showing another typical operational example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a diagram showing a computer network 10 to which the present invention may be applied. To the computer network 10 are connected a computer 12 as one target node which provides service and computers 14 as a plurality of initiator nodes which request service from the target node. The computer network 10 shown in Figure 1 has a ring topology, but the present invention can also be applied to a computer network of another topology such as a star topology or bus topology as long as the topology is such that at least one target node and a plurality of initiator nodes are connected to the network.

Figure 2 is a diagram showing one example of the hardware configuration of the target node 12 in Figure 1. As shown in the figure, the target node 12 consists essentially of a central processing unit (CPU) 20, a memory 22, and a network interface unit 24. The CPU 20 executes programs loaded into the memory 22 from various recording media.

The network interface unit 24 includes a register for storing a collect epoch (CE), a parameter consisting of at least one bit and used in the processing described later, and a register for storing a service epoch (SE), a parameter consisting of the same number of bits as that

of the CE. The network interface unit 24 further includes a counter CC corresponding to the CE and a counter SC corresponding to the SE. The number of bits of the counter CC is equal to that of the counter SC, and is determined according to the number of initiator nodes 14.

Figure 3A is a diagram showing the format of a request packet transmitted from an initiator node 14 to the target node 12; only those portions concerned with the present invention are shown here. The RETRY field consists of one bit; a bit value of 0 indicates that the request packet is related to a first request, while a bit value of 1 indicates that the packet is sent as a retry request which is issued after the previous request is rejected. The EPOCH field consists of the same number of bits as the number of bits of the collect epoch CE or the service epoch SE, and has meaning only when the value of the RETRY bit is 1. The meaning of each field will become apparent in the description given later.

Figure 3B is a diagram showing the format of a reply packet transmitted from the target node 12 to the initiator node 14; only those portions concerned with the present invention are shown here. The REJECT field consists of one bit. The target node 12 responds by setting the REJECT bit to 0 when accepting the request from the initiator node 14, and by setting the REJECT bit to 1 when rejecting the request. In Figure 3B also, the EPOCH field consists of the same number of bits as the number of bits of the collect epoch CE or the service epoch SE, and has meaning only when the value of the REJECT bit is 1. The meaning of each field will become apparent in the description given later.

Figures 4A and 4B are a flowchart illustrating the sequence of processing performed at the target node 12 when a request is received. At the target node 12, the collect epoch CE, the service epoch SE, the collect counter CC, and the service counter SC are all

When a request is received from an initiator node 14, first it is determined in operation 102 whether the RETRY bit in the request packet (Figure 3A) is set to 1 or not. When RETRY = 1, that is, when the received request is a retry request, the process proceeds to operation 116; on the other hand, when RETRY = 0, that is, when the received request is the first request, the process proceeds to operation 104.

In operation 104, it is determined whether the value of the collect epoch is equal to the value of the service epoch; when CE = SE, the process proceeds to operation 108, but when CE \neq SE, the process proceeds to operation 106. In operation 108, it is determined whether the service counter indicates 0 and, at the same time, it is determined whether the requested service is available for delivery. The state of the service being available for delivery will be described as "room available". When the conditions in operation 108 are both satisfied, the process proceeds to operation 112 where the first request is accepted and the reply packet (Figure 3B) with the REJECT bit set to 0 is sent to the requesting initiator node 14.

On the other hand, if the conditions in operation 108 are not satisfied, the process proceeds to operation 110 where the collect epoch CE is incremented and the collect counter CC is set to 1. Next, in operation 114, the REJECT bit is set to 1, and the reply packet (Figure 3B) is sent to the requesting initiator node 14. At this time, the current value of the collect epoch CE is set in the EPOCH field of the reply packet.

In operation 106, which is carried out when it is determined that CE \neq SE in operation 104, the collect counter CC is incremented. Next, the processing in operation 114 described above is carried out.

Before proceeding to the description of the process

of Figure 4B, the process performed at the initiator node when the reply packet is received will be described with reference to the flowchart of Figure 5. When the reply from the target node 12 is received, first it is
5 determined in operation 202 whether the REJECT bit in the reply packet (Figure 3B) is set to 1 or not. When REJECT = 1, that is, when the previously sent request has been rejected, the process proceeds to operation 204; on the other hand, when REJECT = 0, that is, when the request is
10 accepted, nothing is done.

In operation 204, a prescribed time interval is allowed to pass. Then, in the next operation 206, the RETRY bit is set to 1 in order to transmit a retry request and the request packet (3A) thus set is sent to
15 the target node 12. At this time, the value of the EPOCH carried in the received reject reply packet is copied to the EPOCH field of the request packet.

Turning back to Figures 4A and 4B, in operation 116 which is carried out when it is determined that RETRY = 1 in operation 102, it is determined whether the condition "room available" is satisfied; if the result shows YES,
20 the process proceeds to operation 118, but if the result shows NO, the process proceeds to operation 128.

In operation 118, it is determined whether the value
25 of the collect epoch CE is equal to the value of the service epoch SE and, at the same time, the service counter SC indicates 0. If the result shows YES, that is, if $CE = SE$ and $SC = 0$, the process proceeds to operation 130, but if the result shows NO, the process
30 proceeds to operation 120. In operation 130, the retry request is accepted and the reply packet (Figure 3B) with the REJECT bit now set to 0 is sent to the requesting initiator node 14.

In operation 120, the value carried in the EPOCH
35 field of the request packet is taken as a request epoch RE, and it is determined whether the RE is equal to $SE+1$ and, at the same time, the service counter SC indicates

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attached to the arrow.

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relating to a first request, are sent and are all accepted.

Before long, the target node becomes "room not available"; at this time, when a packet F_4 relating to a first request arrives, the CE is incremented to 1, the CC is set to 1, and a reject reply is returned by attaching CE = 1 to it. As a result, the target node makes a transition to the collect state (CE = SE+1 and SC = 0).

In this collect state, when packets F_5 and F_6 , each relating to a first request, arrive, reject replies are likewise returned by attaching CE = 1 to each, and the CC is incremented from 1 to 2 and from 2 to 3. At this time, when a packet R_4 (with RE=1 attached to it) arrives which carries a retry request for the packet F_4 relating to the previously rejected first request, a reject reply is returned by attaching the same RE to it.

Before long, the target node becomes "room available". At this time, when a packet R_5 (RE=1) carrying a retry request for the previously rejected F_5 arrives, the SE is incremented to 1, the SC is set to CC-1 = 3-1 = 2, and the retry request is accepted. As a result, the target node makes a transition to the service state (CE = SE and SC > 0).

In this service state, when a packet R_4 (RE=1) carrying a retry request for the previously rejected F_4 arrives, the retry request is accepted and the SC is decremented to 1. Next, when a packet R_6 (RE=1) carrying a retry request for the previously rejected F_6 arrives, the retry request is accepted and the SC is decremented to 0. As a result, the target node returns to the idle state (CE=SE and SC=0).

Next, the sequence chart of Figure 8 will be described. In this example, transitions are made from the idle state to the collect state, then to the service state in the same manner as in the example of Figure 7. In the example of Figure 8, however, a packet F_7 relating to a first request arrives when the target node is in the

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5 In this service & collect state, a retry request
whose RE value is equal to the current SE=1 is accepted
and the SC is decremented, while on the other hand, any
first request is rejected by attaching CE=2. When SC
becomes equal to 0, the target node makes a transition to
0 the collect state ($CE = SE+1$ and $SC = 0$). The operation
thereafter is self-explanatory. In this way, the target
node makes transitions between the four states.

In view of this, it is effective to include a timeout process whereby the time elapsing until the SC becomes 0 is monitored and, when a predefined time interval has elapsed, the SC is forcefully reset to 0 to allow the process to proceed further. When providing such a timeout process, it would be worthwhile to construct the epoch with multiple bits. The reason is that, if the epoch consists of multiple bits, when a retry request arrives, the time that the previous request was rejected can be recognized and processing appropriate to the result can be performed.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is
35 therefore to be considered in all respects as illustrative and not restrictive, the scope of the

invention being indicated by the appended claims rather than by the foregoing description and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

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